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Durability of photometric and radiometric properties of non-prescription sun eyewear following simulated care

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Abstract

Introduction. Consumers are presented with a vast array of available sunglass options. Choices for non-prescription sun eyewear include not only frame style, lens color, and tint density, but, most importantly for some consumers, cost, which may vary from under one dollar to over one hundred dollars. Yet all eyewear manufacturers claim to comply with standards designed to protect ocular health by reducing the amount of ultraviolet (UV) radiation to reach the eye. hTV absorbers can be applied to a lens as either a coating or a dye. Previous studies assessed characteristics of non-prescription sun eyewear at the point of sale and durability of UV absorbance of prescription eyewear following simulated care. The current study assessed the durability of UV absorbance and other photometric properties of typical non-prescription sun eyewear following one typical season of simulated cleaning with two conventional regimens, as well as one cycle of cleaning with two unconventional methods.

Methods. We purchased six pair of non-prescription sun eyewear marketed for bright outdoor conditions from each of three cost categories: under $1 5; $1 5 to $30; and over $30. During the first cleaning cycles, the left lens of each eyewear was cleaned with a water-based cleaner available at any optical dispensary, and dried with a soft cloth diaper. The right lens was cleaned with Ivory Liqui-Gel soft soap and warm water, and dried with a Puffs brand tissue. Lenses were cleaned for three cycles of care, each of which simulated 13 weeks. Lenses were then divided into two groups for one additional cleaning cycle. One group was cleaned with 70% isopropyl alcohol and the other group was cleaned with Windex, active ingredient ammonia. Spectrometry from 200 to 1100 nm, in 5-nrn increments, was conducted on each lens at baseline and after each cleaning cycle.

Results. At baseline, one pair of bargain-priced eyewear did not meet minimum requirements for UV absorption. Several other eyewear did not meet standards for other optical characteristics, such as suitability for driving and for color deficient individuals. However, 9 months of simulated cleaning with a recommended cleaner or soft soap did not alter UV absorbance of any of the eyewear. Likewise, 3 months of simulated cleaning with alcohol or glass cleaner had no affect on UV absorbance of any eyewear. For any cleaning regimen, changes to other photometric characteristics were typically within the measurement tolerance of the spectrophotometer and likely not clinically significant.

Conclusion. While there is considerable variability in optical characteristics of non-prescription sun eyewear at baseline, simulated cleaning did not affect the optical performance of any eyewear. Consumers should be confident that most name brand eyewear purchased from a reputable retailer complies with optical and ocular health standards, and that it will withstand a season of typical cleaning. In addition, dispensers should not be concerned about using alcohol to clean eyewear. Key Words: non-prescription

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Durability of Photometric and Radiometric Properties of Non-Prescription Sun Eyewear Following Simulated Care

by

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Biographies

Stacy Cullum is a 1990 graduate of Willits High School in Willits, CA. She attended the University of California at Davis where she earned a B.S. in Physiology. After earning her bachelor's degree, she spent several years working in various fields before deciding on Optometry. She is a member of the Class of 2003 at Pacific University College of Optometry. While in Optometry school, she was a member of Amigos and participated in a mission to Baja, Mexico, providing eye care to the underprivileged. She is also a member of BSK and AOA-PAC.

Stacy is married to her husband of 10 years, Brad, and has two children, Ashley (6 years) and Casey (10 months). After graduation, Stacy plans to return to Northern California to practice Optometry.

Elizabeth Kaye Thomas graduated Magna Cum Laude from the University of Houston with a BS in Human Nutrition and Foods in 1992. She became a registered dietitian in the Army where she initiated an effective diabetic education program. After a four year career as an Army dietitian, and a one year career as an optician at a Denver eyewear store, she began optometric studies with Pacific University College of Optometry. She is currently in her fourth year of study and maintains BSK honor society membership.

Elizabeth plans to practice optometry in the state of Colorado where she hopes to become an expert in vision therapy and disease management. She also hopes to become involved in research to further increase her level of expertise.

Abstract

Introduction. Consumers are presented with a vast array of available sunglass options. Choices for non-prescription sun eyewear include not only frame style, lens color, and tint density, but, most importantly for some consumers, cost, which may vary from under one dollar to over one hundred dollars. Yet all eyewear manufacturers claim to comply with standards designed to protect ocular health by reducing the amount of ultraviolet (UV) radiation to reach the eye. UV absorbers can be applied to a lens as either a coating or a dye. Previous studies assessed characteristics of non-prescription sun eyewear at the point of sale and durability of UV absorbance of prescription eyewear following simulated care. The current study assessed the durability of UV absorbance and other photometric properties of typical non-prescription sun eyewear following one typical season of simulated cleaning with two conventional regimens, as well as one cycle of cleaning with two unconventional methods.

Methods. We purchased six pair of non-prescription sun eyewear marketed for bright outdoor conditions from each of three cost categories: under $15; $15 to $30; and over $30. During the first cleaning cycles, the left lens of each eyewear was cleaned with a water-based cleaner available at any optical dispensary, and dried with a soft cloth diaper. The right lens was cleaned with Ivory Liqui-Gel soft soap and warm water, and dried with a Puffs brand tissue. Lenses were cleaned for three cycles of care, each of which simulated 13 weeks. Lenses were then divided into two groups for one additional cleaning cycle. One group was cleaned with 70% isopropyl alcohol and the other group was cleaned with Windex, active ingredient ammonia. Spectrometry from 200 to 1100 nm, in 5-nm increments, was conducted on each lens at baseline and after each cleaning cycle.

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Key Words: non-prescriptionsun eyewear, sunglasses, ultraviolet, ocular health, lens care, UV.

Introduction

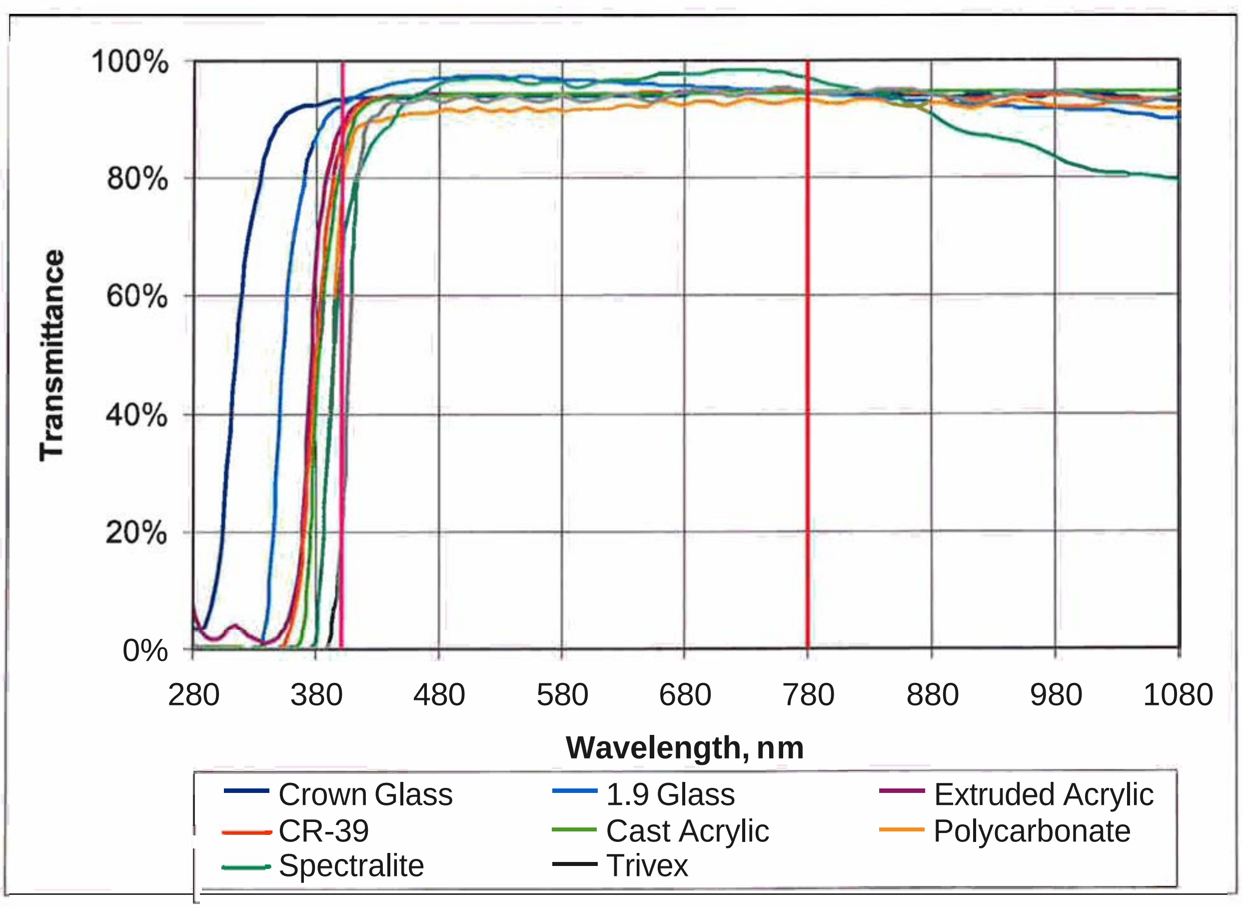
Optometrists and opticians often dispense non-prescription sun eyewear to patients who wear contact lenses or who do not otherwise require a prescription. But the vast majority of non-prescription sun eyewear are sold over-the-counter in retail stores, usually with little direction other than advertising hyperbole. Consumers are presented with a vast array of available options. Choices include not only frame style, lens color, and tint density, but, most importantly for some consumers, cost, which varies from under one dollar to over one hundred dollars. Nonetheless, all eyewear manufacturers claim to comply with standards designed to protect ocular health by reducing the amount of ultraviolet (UV) radiation to reach the eye.

Health reports and the media constantly present the dangers of exposure to UV radiation. While skin cancer is the most often cited evil of UV, many people are aware that UV also can damage their eyes. In addition, long-term exposure to short-wavelength visible light, known as the "Blue Light Hazard," may be potentially as damaging as UV.[1]

Ultraviolet radiation is commonly divided into three spectral zones: near UV (UV-A), from about 320 to 400 nm; middle or erythemal UV (UV-B), from about 290 to 320 nm; and far UV (UV-C), from about 200 to 290 nm.[2] Wavelengths up to 288 nm, which include solar UV-C, are completely filtered by the ozone layer of the atmosphere, and are not a concern for typical sun eyewear; UV-C from industrial sources requires the use of special filters that are beyond the scope of this study.

Different optical materials naturally filter varying amounts of solar UV-A and UV-B. Figure 1 shows the spectral transmittance curves of several clear lens samples. Of the common materials used for ophthalmic lenses, crown glass transmits wavelengths down to 280 nm, 1.9-index glass transmits to about 340 nm, and CR-39 transmits to about 350 nm. Polycarbonate and proprietary plastics, such as Spectralite (AO.SOLA) and Trivex (Hoya), already include W absorbers that essentially block all wavelengths below 380 nm. Acrylic is an inexpensive plastic that may provide reasonable optical quality,[3] but it is not necessarily manufactured with adequate W absorbance for ophthalmic purposes. Samples from one supplier (CYRO Industries, Rockaway NJ) show that cast acrylic transmits to about 365 nm, whereas extruded acrylic transmits to below 280 nm.

Figure 1. Spectral transmittance curves of representative clear lens samples. Also shown are the W and IR cut-off levels, 400 and 780 nm, respectively.



To provide ocular protection in typical outdoor environments, UV is completely filtered by additional absorbers that can be applied to a lens as either a coating or a dye. Most manufacturers claim to filter radiation to 400 nm, and it is likely that they use terms such as "UV 400" to lure customers toward their line of eyewear.[4] But is there any difference in UV protection between sun eyewear that cost only five dollars and others that retail for one hundred dollars? And is the durability of UV absorbance compromised by regular cleaning? Likewise, does regular cleaning adversely affect any of the other photometric properties of sun eyewear?

Three major international standards address the requirements for UV protection and photometric properties of non-prescription sun eyewear at the point of sale:

- American National Standards Institute (ANSI) Z80.3-2001, Standard for Ophthalmics – Nonprescription Sunglasses and Fashion Eyewear – Requirements;[5]
- Australian Standard (AS) 1067.1-1990 – Sunglasses and Fashion Spectacles – Part 1: Safety Requirements;[6] and
- European Standard (EN) 1836-1997 – Personal Eye Protection – Sunglasses and Sunglare Filters for General Use.[7]

However, none of these standards have requirements for durability or maintenance of UV protection with normal use by the consumer. Only one standard, EN 1836-1997, addresses the Blue Light Hazard, but makes recommendations only for lenses that are claimed to filter blue light. Similarly, all standards describe transmittance of near infrared (IR-A) radiation, but have no requirements for its filtration for general purpose eyewear.

Previous studies have shown that off-the-shelf non-prescription sun eyewear in all cost categories provide good protection against UV.[8-12] One recent study found that normal daily washing for one year does not decrease the effectiveness of UV protection of tinted prescription lenses.[13] In the current study, we assessed the durability of UV absorbance and photometric properties of typical non-prescription sun eyewear from three cost categories following repeated cleaning with four different methods.

Review of Standards

Many U.S. and foreign eyewear manufacturers sell their products in many countries, and, therefore, must comply with the applicable standards in effect in each country at the time of sale. Conceivably, the same pair of eyewear may be legal for sale without restrictions in one country, and not legal, or restricted in use, in another country. We present a brief overview of the photometric and radiometric requirements for non-prescription sun eyewear for each of the three major standards currently in effect. Requirements for polarized lenses, gradient density lenses, photochromic lenses, refractive properties, and impact and flammability resistance are beyond the scope of this study and not considered.

Countries that do not formulate their own standards typically adopt all or part of one of the three major standards. Manufacturers and dispensers must verify which, if any, standard is in effect in the country in which they intend to sell non-prescription sun eyewear.

<u>ANSI Z80.3-2001</u>

Primary function of sun eyewear is divided into four groups, based on luminous, or visible light, transmittance (VLT):

- Cosmetic, light – greater than 40%;
  General Purpose, medium to dark – 8 to 40%;
- Special Purpose, very dark – 3 to 8%; and
- Special Purpose, strongly colored – 3% minimum.

Tolerance in VLT is 0.04 density. Thus, a Cosmetic tint may have transmittance as low as 36.5%; a General Purpose tint, as low as 7.3%; and a Special Purpose tint, as low as 2.7%.

Cosmetic and General Purpose tints must have minimum transmittance of wavelengths corresponding to Red, Yellow, and Green traffic signals, and must not chromatically distort the appearance of these signals under average daylight (D65) conditions. In addition, transmittances of wavelengths between 500 and 650 nm must be not less than 20% of the VLT. Special Purpose tints, such as dark or strongly colored ski goggles, by definition do not meet these requirements and should not be used for everyday activities such as driving. Unlike the other standards, there are no specific requirements for use of eyewear by color deficient individuals.

Non-visible spectral zones are defined as UV-A, 315 to 380 nm; UV-B, 290 to 315 nm; and IR-A, 780 to 1400 nm. Mean UV transmittance is based on the spectral zone, lens tint, and exposure level. Cosmetic and General Purpose tints may transmit UV-A at levels up to the VLT under normal use, and up to 50% of the VLT under high and prolonged exposure. For UV-B, these tints may transmit up to 12.5% of the VLT under normal use, and an absolute level of 1% under high and prolonged exposure. For any exposure level, Special Purpose tints may transmit UV-A up to 50% of the VLT and UV-B up to an absolute level of 1%. There are no requirements or recommendations for IR-A transmittance.

AS 1067.1-1990

Classification of sun eyewear is divided into three groups, based on VLT:

- Fashion – minimum 50%;
- General Purpose – 8 to 50%; and
- Specific Purpose – minimum 3%.

Specific Purpose eyewear are subdivided into two additional groups: Type (a), for protection against intense sun glare, with maximum VLT of 25%; and Type (b), for protection against solar UV in specified environments, with no required maximum VLT. Allowable VLT measurement error is 0.2%. Thus, a Fashion tint may have transmittance as low as 49.8%; a General Purpose tint, as low as 7.8%; and a Specific Purpose tint, as low as 2.8%.

For accurate traffic signal recognition, Fashion and General Purpose tints must have minimum transmittances of specific short wavelengths (Violet Factor) and red wavelengths (Red

Factor). Tints that do not meet these requirements are not suitable for Driving. For minimal color distortion, Fashion and General Purpose tints are subject to a maximum Red Factor. Tints that do not meet the minimum Violet Factor and/or maximum Red Factor are not suitable for individuals with Defective Color Vision. Specific Purpose Type (a) tints have similar but more stringent limits for Violet and Red Factors. Specific Purpose Type (b) tints have no such requirements, but should not be used for everyday activities such as driving, especially by color deficient individuals.

Non-visible spectral zones are defined as Near UV, 320 to 400 nm; Erythema1 UV, 300 to 320 nm; and Near IR, 700 to 1300 nm. Mean UV transmittance is based on the spectral zone and lens tint. Fashion, General Purpose, and Specific Purpose Type (a) tints may transmit Near UV at levels up to the VLT; Specific Purpose Type (b) tints may transmit Near UV up to 50% of the VLT. For Erythemal UV, Fashion tints may transmit absolute levels up to 5%; General Purpose tints, up to 1%; Specific Purpose Type (a) tints, up to 0.5%; and Specific Purpose Type (b) tints, up to 0.2%. For Near IR, lenses that claim to filter IR may transmit an absolute level up to 50%; and Specific Purpose Type (a) tints may transmit up to 1.5 times the VLT.

<u>EN 1836-1997</u>

Sun eyewear are divided into five filter categories, based on VLT:

- Category 0 – greater than 80%;
- Category 1 – greater than 43% to 80%;
- Category 2 – greater than 18% to 43%;
- Category 3 – greater than 8% to 18%; and
  Category 4 – greater than 3% to 8%.

Tolerance in VLT for Categories 0 to 3 is 3% absolute, and for Category 4, 30% relative to the nominal VLT. Thus, a Category 2 tint may have transmittance as low as 15%; a Category 3 tint, as low as 5%; and a Category 4 tint, as low as 2.1%. Allowable relative measurement error is 5% for tints over 17.8% nominal VLT; 10% for nominal VLT over 0.44% and up to 17.8%; and 15% for nominal VLT over 0.23% and up to 0.44%.

Category 0 to 3 tints must have minimum transmittance of wavelengths corresponding to Red, Yellow, and Green traffic signals and Blue emergency vehicle signals. In addition, transmittances of wavelengths between 500 and 650 nm must be not less than 20% of the VLT. Tints that do not meet these requirements are not suitable for Driving. Category 4 tints do not meet these requirements and should not be used for everyday activities such as driving.

Blue Light is defined as 380 to 500 nm. Requirements are only for tints that claim Blue Light absorbance or transmittance, and must be within an absolute 0.5% of the claimed value.

Non-visible spectral zones are defined as UV-A, 315 to 380 nm; UV-B, 280 to 315 nm; and IR-A, 780 to 2000 nm. UV-A transmittance is based on lens tint. For mean and spectral UV-A, Category 0 to 2 tints may transmit at levels up to the VLT; Categories 3 and 4 may transmit up to 50% of the VLT. For spectral UV-B, all categories may transmit up to 10% of the VLT. There are no mandatory specifications for IR-A transmittance, but tints that claim to attenuate IR radiation should transmit no more than the VLT.

Methods

Sun Eyewear

We purchased at retail 18 unique pair of non-prescription sun eyewear that were marketed for bright outdoor conditions, with an equal number in each of three cost categories (see Table 1). Since plastic lenses are the most common option available in all cost categories, we did not investigate eyewear with glass lenses, such as Serengeti. Identification of specific lens materials was conducted by an independent laboratory (Polyhedron Laboratories, Houston TX).

Table 1. Physical parameters of each pair of non-prescription sun eyewear tested. Thickness was measured at the geometric center of each lens. Base curve is the average of the horizontal and vertical curvatures, based on index 1.53, at the geometric center with each lens unmounted for at least 24 hours. PC = polycarbonate.

Brand	Retail Price	Material	Color	Thickness, mm		Base Curve, D	
				Left	Right	Left	Right
Category 1 – Premium-Priced							
Calvin Klein	$130.00	CR-39	green	1.80	1.70	6.50	6.31
Guess	$80.00	CR-39	brown	1.88	1.88	6.12	6.12
Kenneth Cole	$100.00	CR-39	gray	1.74	1.75	6.00	6.12
Nike	$110.00	PC	brown	1.64	1.70	9.00	9.00
Oakley	$95.00	PC	gray	1.62	1.59	8.62	8.62
Ralph Lauren	$78.00	CR-39	gray	1.93	1.88	5.81	6.31
Category 2 – Mid-Priced							
Cherokee	$14.99	Acrylic	brown	2.46	2.44	6.06	6.00
HC Driver	$15.00	PC	brown	1.70	1.73	5.75	5.81
Hillard & Hanson	$20.00	Acrylic	gray	2.04	2.03	6.00	6.06
Osh Kosh	$25.00	PC	brown	1.64	1.63	6.12	6.12
Riviera	$18.00	Acrylic	brown	2.18	2.26	8.00	8.00
Visual Science	$22.00	Acrylic	green	2.10	2.08	8.00	8.00
Category 3 – Bargain-Priced							
HD Driving Lens	$5.00	Acrylic	gray	2.02	2.02	6.06	6.12
I. Gear	$7.99	Acrylic	brown	2.08	2.04	8.50	8.12
Jet Vision (1)	$0.99	Acrylic	gray	2.41	2.40	8.00	8.00
Jet Vision (2)	$0.99	Acrylic	gray	1.94	1.95	6.00	6.00
Leisure Time	$4.99	Acrylic	gray	2.40	2.40	6.12	6.00
UV 500	$5.00	Acrylic	gray	1.92	1.85	6.25	6.12

Category 1 eyewear were premium-priced, mean cost $98.83, purchased from optical dispensaries and specialty sunglass stores. Category 2 were mid-priced, mean cost $19.17, and all but HC Driver were purchased from reputable discount and department stores. Category 3 were bargain-priced, mean cost $4.16, purchased at roadside stands and gas stations. The HC Driver eyewear was a single-pane shield purchased at a roadside stand; all other eyewear were dual-lens designs. Most of the bargain-priced eyewear available are from a limited number of manufacturers; thus, we included two pairs of Jet Vision eyewear with unique physical characteristics. Table 1 shows physical parameters of the eyewear tested. Some of the eyewear (not identified in Table 1) were intended for use by children, or were available in children's frames with lenses apparently identical to the adult versions.

Spectral Measurements

Spectrophotometry was performed with a Lambda 20 Spectrometer (Perkin-Elmer, Norwalk CT) at the geometric center of each lens at baseline and after each cleaning cycle (see below). Transmittance was measured over the range of 200 to 1100 nm in 5-nm increments. All standards suggest testing IR wavelengths greater than 1100 nm, which is beyond the range of the spectrophotometer. This is not problematic, since none of the standards currently have IR requirements for the type of lenses tested in this study. Calculations based on IR transmittance, suggested by the different standards, are based on the maximum wavelength of 1100 nm.

Calibration measurements show that the spectrophotometer exceeded requirements of the standards, in that measures for any spectral zone were accurate to within 0.2% and repeatable to within 0.03%.

Cleaning Regimens

Lenses were removed from their frames and marked in a comer with indelible ink to indicate correct orientation. Each lens was placed in an individually-marked container and removed only for cleaning and measurement.

Individual lenses were washed with either of two commonly recommended cleaning regimens, soft soap and lens cleaner. Since neither of these methods produced clinically significant changes in the photometric or radiometric properties of any lens (see Results), we also cleaned the lenses with two unconventional methods: alcohol and household glass cleaner. Many dispensers use alcohol to clean ink marks from lenses. Likewise, consumers may mistakenly use glass cleaner if lens cleaner or soap is not available.

We assumed that the average consumer washes his/her sun eyewear twice per week. Washing each lens 26 times thus simulated 13 weeks of consumer cleaning. For Phase 1, lenses were cleaned for three such cycles, simulating a total of about 9 months of cleaning, or one typical wearing season in an average climate. For Phase 2, with the unconventional regimens, lenses were cleaned for one additional cycle (i.e., 26 cleanings).

In Phase 1, right lenses were washed using Ivory Liqui-gel hand cleaner from a pump dispenser (Procter & Gamble, Inc., Cincinnati OH). Lenses were first wet with warm water, then soap was applied in the amount about the size of an M&M and rubbed on each surface in a circular manner for approximately 10 seconds. Lenses were rinsed with warm water and dried with a Puffs brand tissue (Procter & Gamble, Inc., Cincinnati OH). Left lenses were cleaned using a water-based lens cleaner in a spray pump (Quality Accessories, Inc., Munster IN), similar to that available from many optical dispensaries. One spray of the cleaner was applied to each surface of the lens and then wiped in a circular manner using a soft cloth diaper for approximately 10 seconds until the lenses were dry.

In Phase 2, equal numbers of lenses from each cost category and Phase 1 cleaning method were divided into two groups. Group 1 lenses were cleaned using a disposable alcohol pad saturated with 70% isopropyl alcohol (The Kendall Company, Mansfield MA). Each surface of the lens was wiped with an alcohol pad for approximately 10 seconds in a circular fashion. A new pad was used for each lens for each cleaning. Group 2 lenses were cleaned by spraying on each surface of the lens Windex glass cleaner (S.C. Johnson & Son, Inc., Racine WI), active ingredient ammonia, and wiping dry with a Puffs tissue for approximately 10 seconds.

In both phases, lenses were not handled and allowed to air dry, if necessary, for a minimum of 15 minutes between cleanings. While surface scratches and haze produced by the cleaning regimens were not assessed directly in this study, casual observation showed that such mechanical changes were minimal.

Results

Baseline Measurements

Table 2 shows the baseline photometric and radiometric properties of each lens tested, and Table 3 shows the baseline compliance with each of the three major standards. Note that ANSI 280.3-2001 and AS 1067.1-1990 calculate VLT based on Standard Illuminant C, reported in Table 2, whereas EN 1836-1997 requires the use of Average Daylight D65 (not shown in Table 2). For any lens in this study, calculations of VLT's based on these two illuminants differ by an absolute value of less than 0.14%.

The average VLT for all eyewear in the current study is 12.8%, standard deviation 3.37%. Analysis of variance (ANOVA) shows that there are no significant differences in VLT between right and left lenses ($p = 0.928$), or between the three cost categories ($p = 0.991$). However, two pair of eyewear, Kenneth Cole and Cherokee, had VLT's of less than 8%, which would disqualify them from general use for any standard (see Table 3). Nonetheless, VLT's for both of these eyewear are within the allowable tolerances for general purpose lenses for at least two of the major standards.

All but one pair of eyewear absorbed 99.9% or higher of UV-A and UV-B. The UV 500 eyewear absorbed on average only 95.6% of UV-A and 97.6% of UV-B. Even with this outlier, ANOVA shows no significant differences in UV absorbance between lenses or between cost categories (all $p > 0.14$).

Table 2. Baseline photometric and radiometric transmittances of each lens of non-prescription sun eyewear tested. Luminous (380-780 nm) and Near Infrared (780-1100 nm) transmittances based on calculations defined in ANSI Z80.3-2001; Blue Light (380-500 nm) transmittances based on calculations defined in EN 1836-1997.

Brand	Luminous, %		Near Infrared, %		Blue, %	
	Left	Right	Left	Right	Left	Right
Category 1 – Premium-Priced						
Calvin Klein	15.46	15.93	94.01	94.24	6.63	6.90
Guess	13.93	13.13	94.17	94.13	7.05	6.43
Kenneth Cole	7.91	7.74	94.10	94.09	7.50	7.48
Nike	17.03	17.04	35.25	35.62	9.28	9.28
Oakley	8.18	8.28	37.12	36.24	9.23	9.33
Ralph Lauren	13.07	12.73	94.03	94.07	8.54	8.21
Category 2 – Mid-Priced						
Cherokee	7.37	7.41	63.23	63.69	3.06	3.07
HC Driver	12.57	11.92	35.46	33.67	3.53	3.41
Hillard & Hanson	13.53	13.61	40.05	40.07	11.37	11.44
Osh Kosh	20.56	20.66	37.59	37.64	11.46	11.54
Riviera	10.61	9.89	70.47	70.01	6.38	5.86
Visual Science	12.75	12.86	42.01	42.14	8.87	8.96
Category 3 – Bargain-Priced						
HD Driving Lens	15.88	17.14	44.90	46.82	15.72	16.89
I. Gear	12.06	12.37	71.46	71.55	5.50	5.70
Jet Vision (1)	12.34	12.41	38.77	38.86	12.55	12.64
Jet Vision (2)	14.52	14.89	39.88	41.55	12.21	12.49
Leisure Time	10.70	10.85	37.37	37.18	10.29	10.32
UV 500	11.36	11.80	44.32	44.70	10.93	11.33

Table **3.** Compliance with U.S. (ANSI), Australian (AS) and Europoean (EN) photometric standards at baseline for each pair of non-prescription eyewear tested. All failures noted are for both lenses in all but one case (Guess) of non-compliance with the Australian standard for suitability for defective color vision. Determination of eyewear Function, Classification, and Category do not take into account allowable tolerances for each standard. See text for descriptions of standards.

Brand	ANSI Z80.3-2001		AS 1067.1-1990		EN 1836-1997	
	Function	Compliance	Classification	Compliance	Category	Compliance
Category 1 – Premium-Priced						
Calvin Klein	General Purpose	Meets all standards	2. General Purpose	Fails Violet Factor, Driving	3	Meets all standards
Guess	General Purpose	Meets all standards	2. General Purpose	Fails Color Vision	3	Meets all standards
Kenneth Cole	Special Purpose	Meets all standards	3. Specific Purpose	Fails Red Factor, Driving, Color Vision	4	Fails Driving
Nike	General Purpose	Meets all standards	2. General Purpose	Meets all standards	3	Meets all standards
Oakley	General Purpose	Meets all standards	2. General Purpose	Meets all standards	3	Meets all standards
Ralph Lauren	General Purpose	Meets all standards	2. General Purpose	Meets all standards	3	Meets all standards
Category 2 – Mid-Priced						
Cherokee	Special Purpose	Meets all standards	3. Specific Purpose	Fails Red Factor, Violet Factor, Driving	4	Fails Driving
HC Driver	General Purpose	Fails D65	2. General Purpose	Fails Violet Factor, Driving, Color Vision	3	Meets all standards
Hillard & Hanson	General Purpose	Meets all standards	2. General Purpose	Meets all standards	3	Meets all standards
Osh Kosh	General Purpose	Meets all standards	2. General Purpose	Meets all standards	2	Meets all standards
Riviera	General Purpose	Meets all standards	2. General Purpose	Fails Color Vision	3	Meets all standards
Visual Science	General P ose	Meets all standards				Meets all standards
Category 3 – Bargain-Priced						
HD Driving Lens	General Purpose	Meets all standards	2. General Purpose	Meets all standards	3	Meets all standards
I. Gear	General Purpose	Meets all standards	2. General Purpose	Fails Color Vision	3	Meets all standards
~~Jet Vision (1)~~	~~General Purpose~~	~~Meets all standards~~	~~2. General Purpose~~	~~Meets all standards~~	3	Meets all standards
Jet Vision (2)	General Purpose	Meets all standards	2. General Purpose	Meets all standards	3	Meets all standards
~~Leisure Time~~	~~General Purpose~~	~~Meets all standards~~	~~2. General Purpose~~	~~Meets all standards~~	~~3~~	~~Meets all standards~~
UV 500	General Purpose	Fails UV-B Normal & High Exposure	2. General Purpose	Fails W - B	3	Fails Spectral UV-B

While there is no significant difference between right and left lenses for IR-A transmittance ($p = 0.997$), ANOVA reveals a significant difference between cost categories, $F(2,30) = 7.05$, $p = 0.003$. Premium-priced eyewear had an average IR-A transmittance of 74.8%, whereas mid- and bargain-priced eyewear had average transmittances of 48.0% and 46.4%, respectively. Across cost categories, seven pair of eyewear had an average IR-A transmittance of 83.1% and 11 pair had an average transmittance of 39.4%. At this time, these are merely interesting findings, since none of the international standards have requirements for IR for the type of lenses under test.

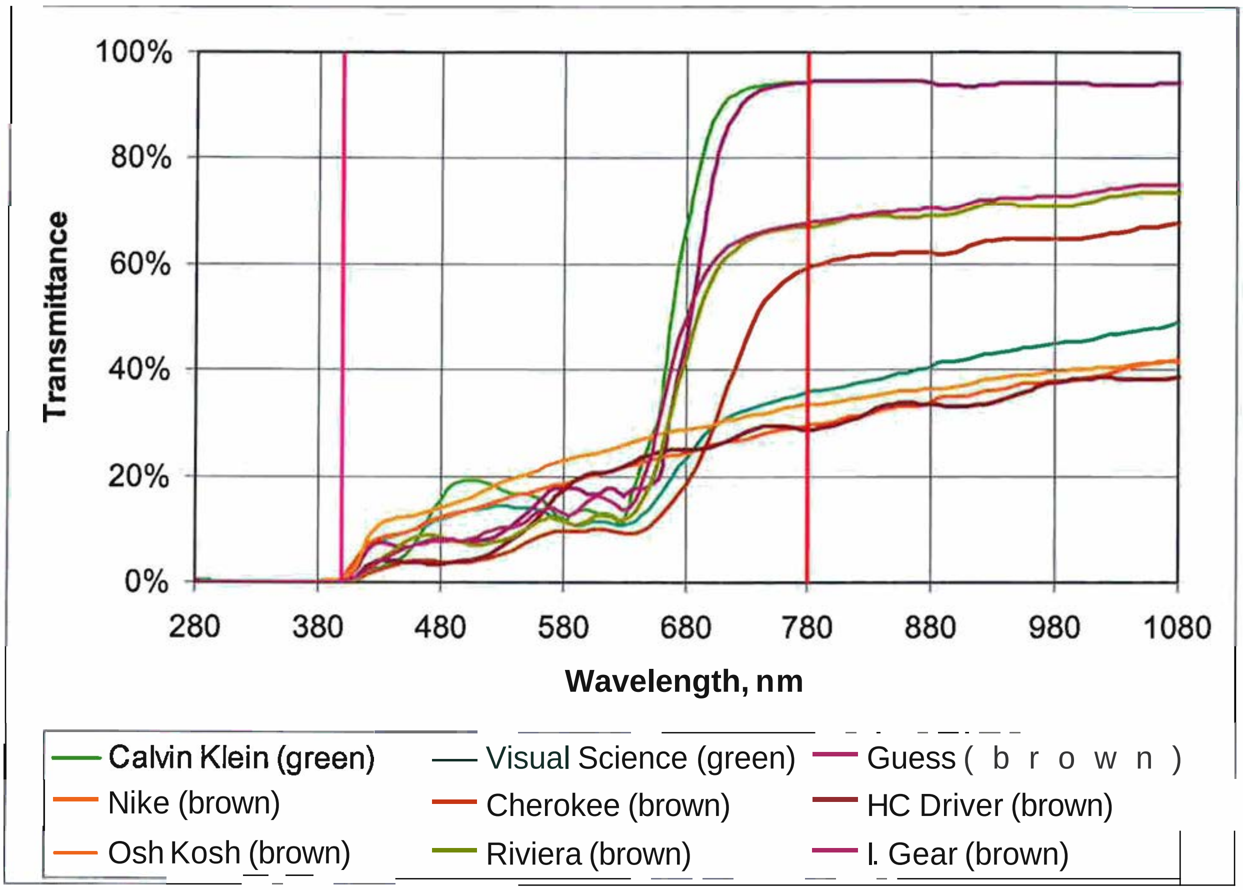
Figure 2 shows the spectral transmittance curves at baseline, averaged over the right and left lenses, for each eyewear tested. Figure 2a includes the nine eyewear that had either green or brown tints, and Figure 2b includes the nine eyewear that had gray tints.

Similarly, there is no significant difference between right and left lenses for Blue Light transmittance ($p = 0.997$), but ANOVA reveals a significant difference between cost categories, $F(2,30) = 6.24$, $p = 0.005$. Bargain-priced eyewear had an average Blue Light transmittance of 11.4%, whereas premium- and mid-priced eyewear had average transmittances of 8.0% and 7.4%, respectively. As with IR transmittance, this is an interesting finding, but no standards have requirements for Blue Light for the type of lenses under test.

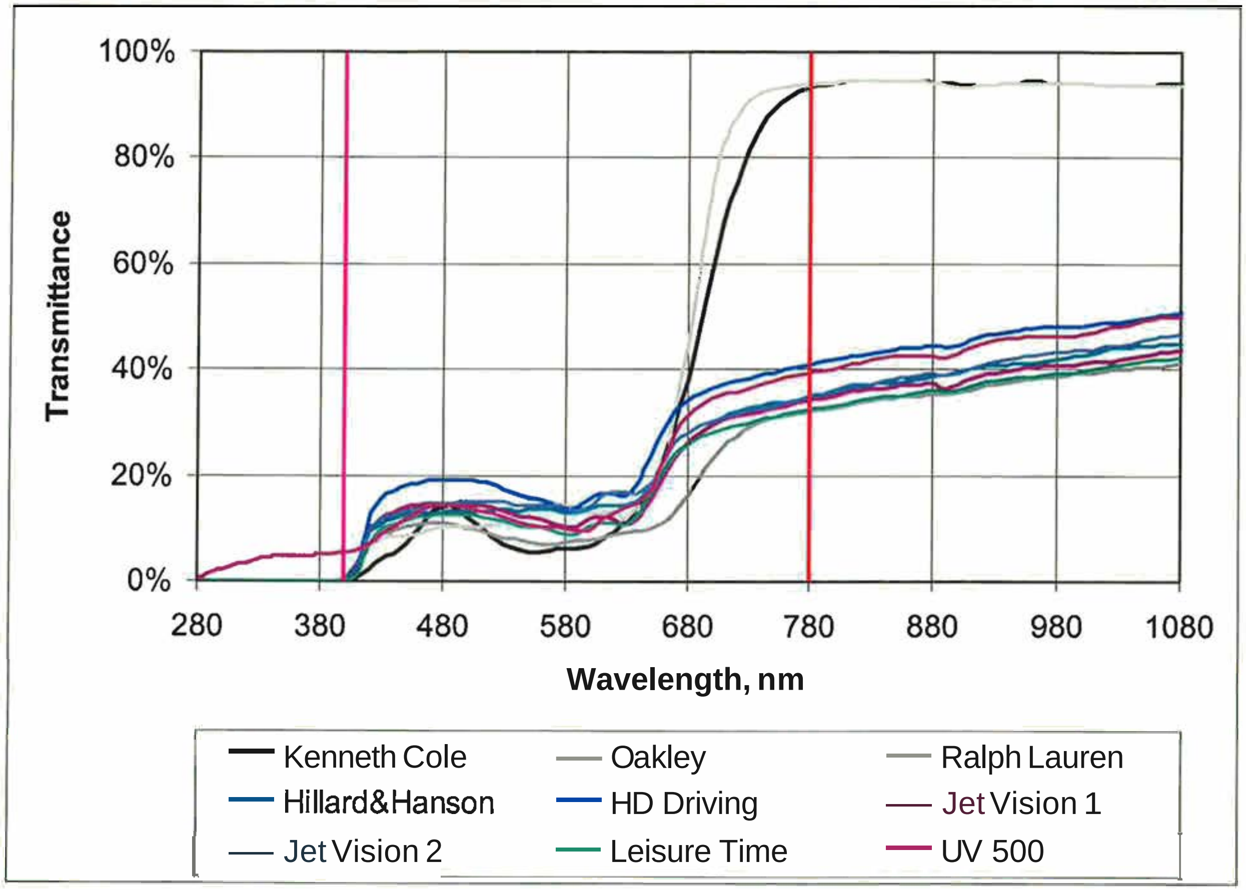
Note that at least one pair of eyewear in each cost category does not meet at least one component of each of the three major standards.

Figure **2.** Spectral transmittance curves for (a) green and brown and (b) gray test eyewear. Each curve is the average of the respective right and left lenses. Also shown are the UV and IR cut-off levels, 400 and 780 nm, respectively.

(a)



(b)



Phase 1 – Soft Soap vs. Lens Cleaner

ANOVA shows that UV-A and UV-B absorbance of any lens did not change significantly after any of the three cleaning cycles for either of the regimens, $p > 0.29$ for all analyses.

Figure 3 shows the average VLT and Blue Light transmittances, and Figure 4 shows the average IR transmittances, at baseline and after each cycle for the lenses within each cleaning regimen. Standard error bars are also shown in each figure.

Figure 3. Average VLT and Blue Light transmittances, with standard error bars, for individual lenses at baseline and after each cleaning cycle with soft soap and lens cleaner.

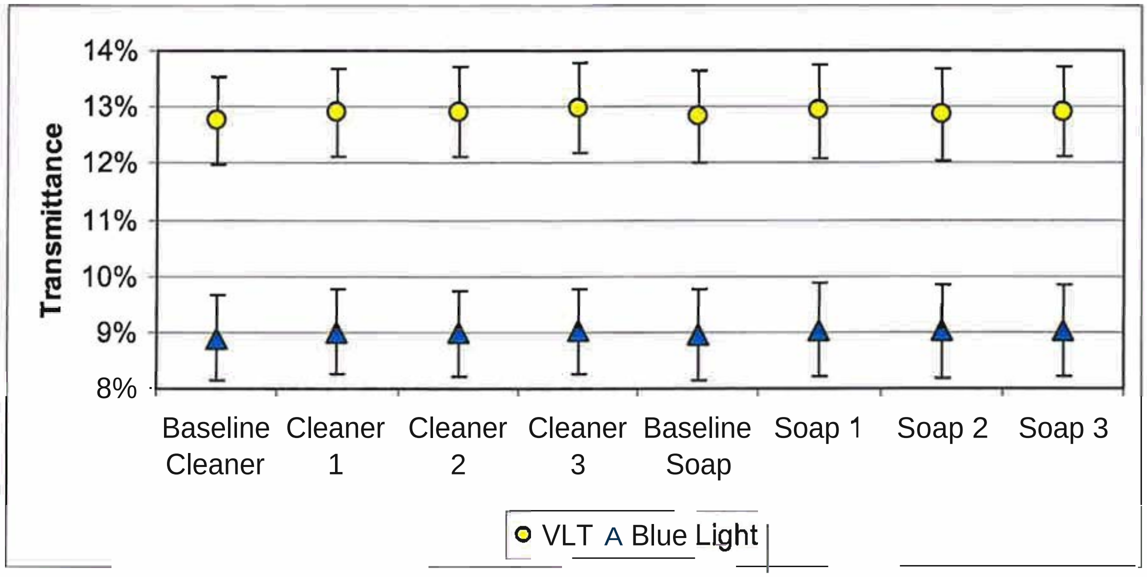
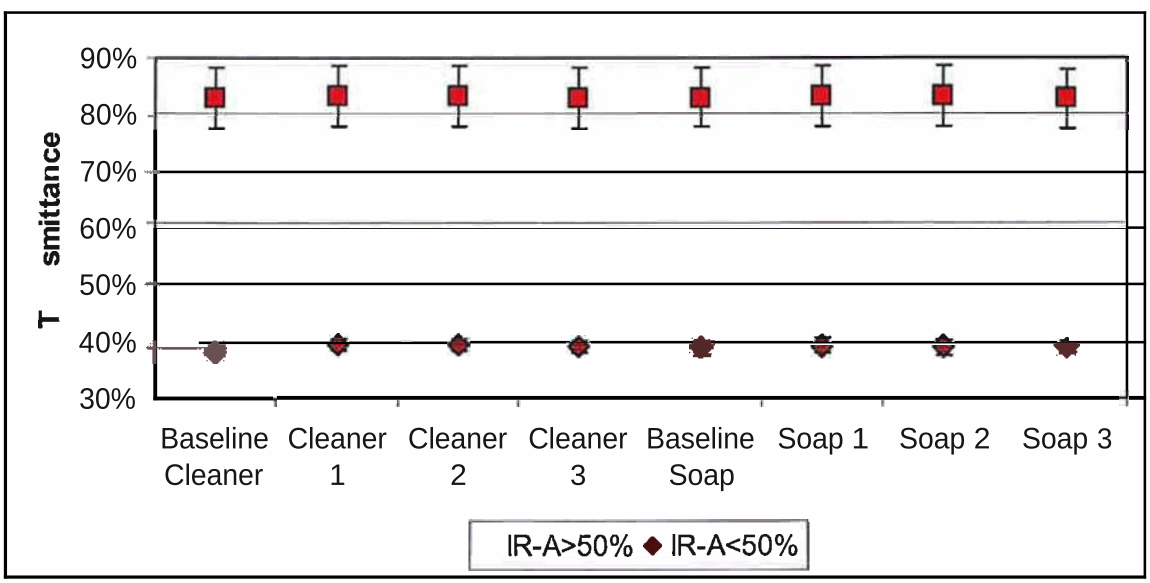


Figure 4. Average IR transmittances, with standard error bars, for individual lenses at baseline and after each cleaning cycle with soft soap and lens cleaner. For lenses with baseline IR-A > 50%, n = 7, and with baseline IR-A < 50%, n = 11 (see Table 2 for specific eyewear).



For either cleaning regimen, VLT, Blue Light, and IR transmittances did show significant changes with respect to cleaning cycle (all $p < 0.005$). However, VLT changed on average by less than 0.14%, Blue Light by less than 0.12%, and IR by less than 0.26%. All of the differences are within, or close to, the tolerance of the spectrophotometer and should not be considered clinically significant. No other main or interaction effects were significant at the 0.05 level.

Phase 2 – Alcohol vs. Glass Cleaner

ANOVA shows that UV-A and UV-B absorbance of any lens did not change significantly for either of the cleaning regimens, $p > 0.13$ for all analyses. Likewise, VLT and Blue Light transmittance did not change significantly, $p > 0.05$ for all analyses.

However, IR transmittance did change significantly, $F(1,32) = 25.70$, $p = 0.000$. For alcohol, average transmittance increased by 0.22% for the seven high-IR-A transmittance eyewear and by 0.27% for the eleven low-IR-A transmittance eyewear. For glass cleaner, average transmittance increased by 0.56% for high-IR-A transmittance eyewear and by 0.46% for low-IR-A transmittance eyewear. The alcohol regimen changes are close to the measurement tolerances of the spectrophotometer and likely not clinically significant, but it is possible that the glass cleaner changes are clinically significant.

Discussion

The durability of photometric and radiometric properties of non-prescription sun eyewear has been demonstrated under two conventional, and two unconventional, daily cleaning regimens, regardless of the cost of the eyewear. Most of the statistically significant changes measured fall within or close to the tolerances of the spectrophotometer, and are likely not clinically significant. The only apparent change that may be clinically significant is an average increase of IR-A transmittance of about 0.5% following one cleaning cycle (i.e., 26 washings) with glass cleaner. Such a change nonetheless may not have clinical significance for patients, since there currently are no requirements in any of the three major standards for IR-A transmittance for the type of eyewear tested in this study.

Therefore, consumers should not worry about using soap or lens cleaner to wash their eyewear, nor should they be concerned if they mistakenly use glass cleaner with ammonia on occasion. Likewise, dispensers may use alcohol-based cleaners without fear of altering the transmittance characteristics of any off-the-shelf eyewear.

What should be of greater concern to consumers and dispensers alike are the actual characteristics of the sun eyewear. For a given patient and the environmental conditions under which he/she intends to use the eyewear, the lenses may be too dark or too light, the tint may adversely affect color perception, and, generally speaking, the eyewear may not be suitable for the visual demands. Most patients will be able to judge if a tint density is appropriate, but optometric physicians and dispensers should offer advice on UV and Blue Light protection, and on tint color, especially to color deficient patients. One pair of each of the premium- and mid-priced eyewear were so dark that they barely met ANSI VLT tolerances for general purpose eyewear. In addition, several eyewear were not suitable for driving or for use by color deficient individuals, based on European and Australian standards.

Most important, though, one pair of bargain-priced eyewear, ironically labeled "UV 500," did not provide acceptable UV protection from the outset. Thus, consumers should be encouraged to purchase sun eyewear only from reputable outlets and dispensaries, avoiding roadside stands and bargain retailers who may not be willing or able to stand behind the products they sell.

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